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Handaxe Types, Colonization Waves, and Social Norms in the British Acheulean

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Abstract

The handaxes of north-western Europe are some of the most varied in the Acheulean world, with the meanings of that variation debated since the late nineteenth century. To reassess handaxe form in this region, we performed a 3D morphometric analysis of 150 handaxes from five British Acheulean assemblages: Boxgrove, High Lodge, Hitchin, Swanscombe Middle Gravels, and Broom. Regression analyses indicate the importance of the effects of allometry and the assemblage to which the handaxe belongs on shape variation. Marine Isotope Stage (MIS) 11c assemblages Hitchin and Swanscombe occupy significantly different shape space from both the MIS13 assemblages Boxgrove and High Lodge, and the MIS9 assemblage of Broom. Handaxe types such as ovates, cordates, limandes, triangular, and ficrons occupy unique areas of shape space in plan form. Twisted-profile and plano-convex handaxes are distinctive in their profile forms from handaxes with similar plan forms. We suggest that the distinctive and difficult to produce handaxes types that characterize the British Late Acheulean were reproduced according to normative expectations of what handaxes should look like. Different occupation phases in MIS13, MIS11c, and MIS9 are characterized by different suites of handaxe types, likely as the result of different waves of colonization with different normative social traditions.

Keywords: Normativity; 3D morphometrics; Boxgrove; Hitchin; Swanscombe; Plano-convex; Twisted symmetry

Introduction

Archaeological 'cultures' are defined by suites of co-occurring traits with temporal and geographic localization. The maintenance of such cultures over generations is enhanced by the human propensity for normativity: the societal level way of making, doing, or saying things, that ensures greater uniformity of behaviour than would otherwise derive from the cultural ancestry and connections of individuals (Claidière and Whiten, 2012). Normativity is not merely of concern for archaeological inference, it is a uniquely human trait with a critical role in a range of behaviours including language and morality (e.g. Roughley and Bayertz, 2019; Tomasello and Vaish, 2013). Determining when and why it emerged is a significant goal for human evolutionary studies but one with which researchers are only just beginning to engage (Finkel and Barkai, 2018; Shipton, 2019b; Sterelny, 2014, 2019). In this paper we explore what may be an early expression of normativity; handaxe types and different archaeological cultures in the British Late Acheulean.

Acheulean handaxes are perhaps the most ubiquitous and recognisable shaped tool in prehistory, although as a group they are far from homogenous in technology or form. Within-site variation is wide, but nonetheless almost all Acheulean localities show one or more modal shapes, some highly characteristic. Handaxe form can thus be understood hierarchically: there are general modal shapes in terms of which all assemblages may be described (Schick and Clark, 2003; Shipton, 2013), and in some assemblages there are distinctive technological or morphological features that warrant the use of specific named types. Experimental evidence confirms the intuitive observation that the variation seen in handaxe form goes beyond functional requirements (Bordaz, 1970; Key and Lycett, 2017). There is a limited shape space in which the constraints of knapping will allow the tool to vary, so there is inevitable convergence and overlap in the range of handaxe types at regionally and temporally disparate sites. Nonetheless, several contrasting examples of handaxe types are to be found in the Acheulean of south-eastern Britain, which are rare or absent in the rest of the Acheulean world.

South-eastern Britain lay at the north-western extremity of the Acheulean world. Different shapes of Acheulean handaxes have long been recognized as characterizing different assemblages in the British Acheulean (Roe, 1968; Wymer, 1968). Early attempts to make sense of these shapes as either *fossile directeurs* of linear chronological stages (e.g. Commont, 1912; de Mortillet, 1873) or as cultural markers of different 'ethnic' groups (Breuil, 1932) were ultimately unsuccessful, principally due to inadequate chronological frameworks. A morphometric analysis to systematize British handaxe variation was first attempted in the 1960's by Derek Roe (Roe, 1964, 1968). Using the ratios of width to length, of tip width to base width, and of base length to total length, Roe divided British handaxes into pointed versus ovate types and assigned assemblages into seven groups (Table 1). However, an overall chronological pattern of a shift from pointed to ovate (or vice versa) over time did not emerge.

Explanations of handaxe shapes instead shifted to focus on the influences of initial clast form (White, 1998), and the extent of reduction (McPherron, 1999). Experimental tests of these hypotheses have shown that while they may influence handaxe form, these effects are not strong enough to produce the diversity that is visible in the archaeological record (Eren et al., 2014; Shipton and Clarkson, 2015b).

In light of improved dating of river terrace sequences in southern Britain, chronological patterning in handaxe types has recently come to the fore again (Bridgland and White, 2014, 2015; Wenban-Smith, 2004; White et al., 2018). White and colleagues propose a schema whereby successive waves of colonization introduced different handaxe forms to Britain in different temperate periods between Marine Isotope Stages (MIS) 15 and 9 (621,000 - 300,000 years ago) (Table 1 and Figure 1). They further suggest that in the sub-stages of Marine Isotope Stage 11 there are geographical differences within south-eastern Britain that are related to cultural traditions rather than clast form (White et al., 2019) (Table 1). The dating at many of these sites remains imprecise and may conflate different sub-stages, while temperate periods would have lasted several thousand years. However, primary context open-site assemblages typically represent short-lived occupations, and continuity in knapping traditions has been demonstrated over tens of thousands of years in Acheulean sites with multiple occupation layers (Sharon et al., 2011). That Britain was periodically abandoned during cold periods is perhaps one reason why handaxe form is particularly distinctive between assemblages here, as individual sites were not usually occupied for extended periods.

Table 1 includes both broad characterization of assemblages on a pointed-rounded spectrum as well as the proportions of specific types. A Multinomial Logistic Regression analysis of this data (model fit χ^2=52.112, df=15, p<0.001) indicates it is effective in assigning assemblages to marine isotope stages, with 100% of assemblages correctly classified. In this paper we propose to test the hypothesis of different handaxe traditions in different isotope stages using a more powerful quantification and statistical analysis of shape, on a sample of handaxes from five of the assemblages in Table 1. If occupation in different stages represents different waves of colonization, we should be able to detect significant differences in shape between stages, and sites within the same temperate period should be more similar to each other than those from different stages.

Several factors might explain why different assemblages are characterized by different handaxe shapes. Conformity to the most common model and random drift of that model over time could lead to divergence between assemblages. Prestige bias resulting in the copying of a handful of experts each with their own idiosyncratic style might explain multiple types. An alternative hypothesis is that handaxe forms might be maintained by normativity (Finkel and Barkai, 2018; Shipton, 2019b), the uniquely human tendency to conform to the particular behavioural modes of a social group that exist independently of dyadic relationships (Anderson and Dunning, 2014).

Table 1. Key British Acheulean sites; their probable marine isotope stage; the percentage of pointed versus ovate by Roe metric and their group according to Roe; and the percentage of distinctive types for which data is available – twisted, ficrons, cleavers, and tranchet. Data from White (unpublished; White, 1996, 1998; White and Plunkett, 2004), Roe (1968), Cranshaw (1983), and Hosfield and Green (2013).

Site	Probable Age	% Metrical Pointed: Rounded Handaxes	Roe Group	% Twisted	% Ficrons	% Cleavers	% Tranchet	N	Reference for dating
Baker's Farm	MIS9	56:44	I	0	8.5	14.5	15.8	152	(Bridgland, 1994)
Stoke Newington	MIS9	75:25	I	0	8.6	12.9	3.6	63	(Green et al., 2006)
Cuxton	MIS9-8	60:40	I	0	10	8.5	8	183	(Wenban-Smith, 2004)
Furze Platt	MIS9	74:26	I	0.4	7.5	5.6	5.6	107	(Bridgland, 1994)
Wolvercote	MIS9	67:33	III	0	3.5	1.8	2.1	47	(Bridgland, 1996)
Broom	MIS9-8	61:39	IV	3	2.6	2.7	7.5	997	(Hosfield and Green, 2013)
Swanscombe UL	MIS11a	30:70	VI	22	0	5	39	18	(White et al., 2019)
Bowman's Lodge	MIS11a	24:76	VI	33	0	3.3	47	30	(Bridgland, 1994)
Wansunt	MIS11a	19:81	VI	28	0	0	43	32	(Bridgland, 1994)
Elveden	MIS11c	26:74	VI	36	0	0	42	74	(Ashton et al., 2005)
Foxhall Road Grey Clay	MIS11c	33:67	VI	39	0	5	50	18	(White and Plunkett, 2004)
Hitchin	MIS11c	68:32	VI & II	16	0	1	11	64	(Boreham and Gibbard, 1995)
Hoxne	MIS11a	67:32	II	3.5	0	0	13.5	111	(Ashton et al., 2008)
Dovercourt	MIS11	68:32	II	4	1.8	0	2	165	(Bridgland et al., 1990)
Foxhall Road Red Gravel	MIS11c	70:30	II	5	0	0	11	17	(White and Plunkett, 2004)
Swanscombe MG	MIS11c	82:18	II	0	3.6	1.8	0	159	(Conway et al., 1996)
Highlands Farm	MIS13/12	15:78	VII	0	0	4	32	200	(Wymer, 1999)
Warren Hill Fresh	MIS13	13:85	VII	1.6	0	1.3	30	642	
High Lodge	MIS13	12:82	VII	3	0	7.6	38	68	(Lewis et al., 2019)
Boxgrove	MIS13	15:85	VII	0	0	10	72	81	(Roberts and Parfitt, 1999)
Fordwich	MIS13+	67:33	V	1	0.7	5.1	2	139	(Bridgland et al., 1998)

Samples

To address hypotheses about the sources of British handaxe shape variation, this paper will compare handaxe form between marine isotope stages and between types. To do this we sampled handaxes from five assemblages chosen to reflect the diversity of the British Acheulean: Boxgrove, High Lodge, Hitchin, Swanscombe Middle Gravels, and Broom. These assemblages are from three different regions of south-eastern Britain – eastern England, the Thames Valley, and the southern coast; they are dated to three different marine isotope stages - 13, 11c, and 9 (Figure 1); they feature several distinctive handaxe types such as tranchet-flaked, twisted-profiles, ficrons, and cleavers; and in Broom they include one of the few British assemblages that is not dominated by flint (Table 1). Handaxes were selected at random from collections housed in the British Museum. As post-discard damage will affect analyses of shape (Grosman et al., 2011), any handaxes with more than minor damage were excluded. In the rare instances of typological ambiguity, such as a handaxe versus a discoidal core, or questionable provenance, pieces were excluded.

Boxgrove, West Sussex, is an MIS13 site on the south coast, with handaxes made on primary nodules of chalk flint (Roberts and Parfitt, 1999). Handaxes were sampled from localities 1B, 1BD, BDL, and L30. Boxgrove handaxes tend be rounded, falling on a spectrum from ovate to the classic cordate tear-drop shape. A distinctive feature of the Boxgrove handaxes is the high proportion of tranchet flaking on the tip whereby the distal tip is removed in a single oblique or transverse blow at the end of reduction to leave a sharp straight tip edge (Bergman and Roberts, 1988) (Figure 2). Notably Boxgrove was occupied for less than 150 years (García-Medrano et al., 2018), an archaeological instant in comparison to most Lower Palaeolithic sites, with its handaxes the products of a few generations at most.

High Lodge, Suffolk, is a probable MIS13 site in East Anglia with handaxes made on both fresh flint and secondary clasts from the valley sides of the (now-extinct) Bytham river (Ashton, 1992; Lewis et al., 2019). Handaxes were sampled from both late 19th century antiquarian collections and the 20th century excavation campaigns at the site. High Lodge handaxes tend to be rounded like those of Boxgrove, but also feature some limande forms which are elongate with the edges running parallel around the midpoint (Figure 2).

Hitchin, Hertfordshire is an MIS11c site on the north-eastern edge of the Chiltern Chalk downlands, with handaxes on primary cobbles and large flakes of flint (Ashton et al., 2006; Boreham and Gibbard, 1995). Handaxes were sampled from antiquarian collections of the late 19th and early 20th centuries. Handaxes from Hitchin are sub-pointed and feature a variety of forms. Some of the more distinctive are plano-convex pieces with a pronounced profile asymmetry between a flat and a domed surface, typically on more pointed specimens (Figure 2); and twisted pieces which have a remarkable twisted profile, typically on more rounded specimens (White et al., 2019) (Figure 2). There is a possibility that Hitchin is a palimpsest of two assemblages belonging to two Roe Groups (Table 1), one with more pointed forms and another with more cordates including twisted profile pieces (White et al., 2019).

The Middle Gravel at Swanscombe, on the right bank of the river Thames in Kent, has produced a large MIS11c assemblage of handaxes (Conway et al., 1996). These were made on secondary clasts of flint deposited by the Thames and occasionally large flakes struck from those clasts. Handaxes were sampled from the Barnfield Pit locality recovered by excavations in the early 20th century. The Swanscombe handaxes are some of the most pointed, in plan view some are triangular (Figure 2) while others have the concave edges associated with the British definition of a ficron (Roe, 1982).

Broom, Devon is an MIS9-8 site in the south-west, with handaxes on near-primary chert nodules and large flakes, with occasional secondary flint clasts (Hosfield and Chambers, 2009; Hosfield and Green, 2013). Handaxes were sampled from the antiquarian collections of the gravel pits. There is a great variety of handaxes from Broom and it was once supposed that the site was a palimpsest, however recent work indicates that the majority of handaxes were deposited over single occupation phase (Hosfield and Chambers, 2009).

Several of the types mentioned above are evident at Broom, as well as asymmetrical pieces and cleavers. The distinctive asymmetrical pieces are large with an unflaked area on one side of the butt, possibly a grip. Cleavers have a broad bit at their tip and elsewhere in the Acheulean world are undoubtedly a distinct tool, often made using blanks obtained from prepared cores. In Britain and adjacent regions of northwestern Europe, the cleaver has no such technological definition, and is sometimes regarded as just another type of handaxe (White, 2006) (Figure 2).

Method

Geometric morphometrics is a method of analysing objects as a series of landmark co-ordinates occupying the same shape space. It has the advantage over linear morphometric measurements of retaining relationships between different parts of the object during analysis. Geometric morphometrics is well suited to the analysis of shaped artefacts and has been used on handaxes, in particular, for a number of years. Two dimensional geometric morphometrics have been applied to bifaces, including handaxes since the late 2000s (Buchanan, 2006; Costa, 2010). Lycett and colleagues (Lycett et al., 2006; Lycett et al., 2010) used a bespoke tool to measure 3D landmarks on the most worked hemisphere of bifaces, following Wynn and Tierson's (1990) morphometric method in using a radiating array of measurements. Subsequent methods employed a Microscribe with the same orthogonal configuration (Archer and Braun, 2010), and with orthogonally oriented configurations more akin to the Roe measurements, that took landmarks from both surfaces of the bifaces (Shipton, 2008, 2013). Data collection was then done on 3D scans of handaxes (Shipton and Clarkson, 2015b). The most laborious part of all these methods is taking the co-ordinates of landmarks on the handaxe.

Recently, Herzlinger and colleagues (2017) developed automated software to collect landmarks from 3D scans, allowing magnitudinal increases in the number of datapoints, and thereby finer details of shape variation to be analysed. This AGMT3D program (version 3.01) was used throughout the following analyses (Herzlinger and Grosman, 2018), except for the regression analyses and General Linear Model which were conducted in SPSS.

The AGMT3D program begins with the automated positioning of handaxe scans (Grosman et al., 2008). The protocol positions handaxes so that the plane of intersection between its two largest opposed surfaces is parallel to the XY plane and perpendicular to the Z axis. It then rotates the object so that its maximum length in the XY plane is parallel to the Y axis. For more symmetrical handaxes this protocol closely matches others that maximize the symmetry of the objects (Shipton and Clarkson, 2015b). However, for handaxes with protrusions on the butts or asymmetrical tips there is a disagreement between the protocols, with the AGMT3D program orienting some pieces 'diagonally'. Any handaxe that was oriented by the AGMT3D program more than 5° off the axis of maximum symmetry in the XY plane was eliminated from the analysis. This resulted in the initial sample of 160 handaxes being reduced to 150 pieces (Table 2). Handaxe models were further oriented so that the most domed surface was always designated as the same surface (Shipton and

Clarkson, 2015b), and if neither surface was more domed, then orientation was so that any asymmetries in the tip were protruding in the same direction.

To extract the landmarks, the AGMT3D places a 3D grid on the surface of the object (described in detail in Herzlinger et al., 2017). The maximal length of the handaxe forms the prime meridian of the grid, with either end the poles. Equidistant latitudes are taken at fixed intervals along the maximum length out to the edge of the handaxe, and equidistant longitudes are taken parallel to the maximum length out to the maximum breadth of the handaxe. Semi-landmark co-ordinates are then obtained from the crossing points of the latitudes and longitudes. The user is able to specify the number of latitudes and longitudes, and in this case we chose 50 of each resulting in a total of 5000 landmarks for every handaxe scan (50x50 for each surface). Our previous 3D geometric morphometric study of these same scans used just 18 landmarks per handaxe (Shipton and Clarkson, 2015b).

To compare between assemblages, a Generalized Procrustes Analysis was performed to scale each object to a unitary size, so that the following analyses look at shape in isolation from size. A Principal Components Analysis (PCA) was then performed to determine the main parameters of shape variation among the objects, the results of which are discussed below.

Table 2. Breakdown of samples used in this study by handaxe type. Note that we used a broad definition of ficron as any handaxe with bilateral convexity in plan.

Site	**N**	**Ovate**	**Limande**	**Cordate**	**Triangular**	**Ficron**	**Twisted-profile**	**Plano-convex**	**Cleaver**	**Asymmetrical**
Boxgrove	34	13		18					3	
High Lodge	28	11	6	11						
Hitchin	31		3	4	5	2	5	12		
Swanscombe	26			4	15	7				
Broom	31	3	2	10	3	4			7	2
Total	**150**	27	11	47	23	13	5	12	10	2

Results

The PCA extracts N-1 principal components, in this case 149. We first examined assemblage variability in terms of the mean distance of the multi-dimensional principal components of individual handaxes from the assemblage centroid (Herzlinger and Goren-Inbar, 2019) (Table 3). Results show that Boxgrove is the least variable of all the assemblages, with a Wilcoxon rank-sum test indicating that it is significantly different from the other MIS13 assemblage High Lodge, which is also the next most homogenous (rank-sum=896, p=0.01). This is in keeping with the short duration of occupation at Boxgrove. Hitchin meanwhile is the most variable assemblage, significantly different from the other MIS11c assemblage, Swanscombe (rank-sum=1058, p=0.01), though not significantly different from Broom another assemblage noted for its variability (rank-sum=1050, p=0.3). This provides for support for the suggestion that Hitchin is a palimpsest of two different occupations (White et al., 2019).

Table 3. Assemblage variability expressed as the mean distance of principal components for each handaxe from the assemblage centroid.

Site	N	Variability
Broom	31	302.1
Hitchin	31	313.2
Swanscombe	26	275.8
High Lodge	28	249.5
Boxgrove	34	211.6

The first two principal components explained around half the variability, 37.57% and 11.5% respectively. For our second analysis we examined the scores for the first principal component (PC1) which, like our previous study on these specimens (Shipton and Clarkson, 2015b), essentially distinguishes between pointed (negative values) and rounded (positive values) handaxes.

To test what is driving the variation in PC1 we conducted regression analyses against three variables: length, to test for allometric variation related to ergonomic constraints (Gowlett and Crompton, 1994); the proportion of cortex remaining (as measured from 3D scans), to test for constraints of clast size (White, 1998); and the Scar Density Index (SDI) (Shipton and Clarkson, 2015a), to test for the influence of reduction intensity (McPherron, 1999).

All three variables produced significant correlations (Table 4) with more rounded handaxes being shorter, with less cortex, and higher scar densities. There are multiple explanations for such correlations. For instance, a life history trajectory from pointed to rounded through resharpening phases could explain concomitant reductions in length and cortex, as well as increases in scar density (McPherron, 2006). Alternatively, making a rounded handaxe may necessarily entail greater reduction, with the butts on such pieces being more extensively worked than those of pointed ones. This might preclude the production of rounded pieces on smaller clasts with limited reduction potential (White, 1998).

To tease apart competing explanations, we conducted a General Linear Model using PC1 as the dependent variable, length, cortex proportion, and SDI as covariates, and site as a fixed factor. The resulting model had an adjusted R^2 value of 0.57, indicating these variables were able to explain over half the variation in PC1. With the model taking into account all four variables, the effect of reduction intensity (SDI) disappears, and the effect of cortex proportion becomes very weak, explaining less than 10% of variation in PC1 (Table 5). Length is still an important determinant of PC1 which we think supports the hypothesis of Gowlett (Gowlett and Crompton, 1994) that constraints of hand size were an important influence on handaxe shape, such that longer pieces must necessarily be relatively narrow. By far the most important determinant of PC1 was however the assemblage to which the handaxes belong. This indicates that there are site specific determinants of handaxe shape unrelated to reduction intensity, clast size, or ergonomic constraints.

Table 4. Results of Linear Regression Analyses of PC1 against handaxe length, cortex proportion, and SDI.

	df	F	p	Adjusted R^2
Length	148	29.333	<0.001	0.161
Cortex Proportion	146	39.938	<0.001	0.211
SDI	147	26.649	<0.001	0.149

Table 5. Results of General Linear Model of PC1 with length, cortex proportion, SDI, and site as explanatory variables. The model had an adjusted R^2 value of 0.57.

	F	p	Partial Eta squared
Length	27.32	<0.001	0.164
Cortex Proportion	9.341	0.003	0.063
SDI	1.2	0.275	0.009
Site	22.815	<0.001	0.396
Total	28.623	<0.001	0.59

Our subsequent analyses returned to the original geometric morphometric dataset and used Wilcoxon rank-sum tests to compare interpoint distances between group mean shapes. We compared the MIS13 assemblages from Boxgrove and High Lodge with the MIS11c assemblages from Hitchin and Swanscombe Middle Gravels, finding a significant difference between the two periods (N=120, rank-sum=9610, p<0.01). Figure 3 shows that MIS13 assemblages are more rounded and with their point of maximum thickness close to the middle of the piece, whereas MIS11 assemblages are more pointed with their point of maximum thickness close to the base of the piece. In comparing individual assemblages with the Wilcoxon rank-sum test, no difference was found between the MIS13 assemblages from Boxgrove and High Lodge, but significant differences were noted between the East Anglian assemblages from High Lodge and Hitchin, between the primary clast assemblages of Boxgrove and Hitchin, and between the MIS11c assemblages of Hitchin and Swanscombe Middle Gravels (Table 6).

Table 6. Results of Wilcoxon Rank-Sum test comparing interpoint distances between MIS13 and MIS11 biface assemblages for PCA 1.

Comparison	N	rank-sum	p
Boxgrove v. High Lodge	62	3668	0.3
High Lodge v. Hitchin	59	2652	<0.01
Boxgrove v. Hitchin	65	2899	<0.01
High Lodge v. Swanscombe	54	1751	<0.01
Hitchin v. Swanscombe	57	2746	<0.01
Hitchin v. Broom	62	3435	0.02
Swanscombe v. Broom	57	2420	<0.01

Both Boxgrove and High Lodge have a significant proportion of tranchet flaking in their handaxe assemblages, 19 and 9 pieces respectively in this sample. A Wilcoxon rank-sum test however showed no significant difference between tranchet and non-tranchet group means for these two sites (rank-sum=3755, n=62, p=0.48). This suggests that while tranchet flaking is technologically distinct and creates a distinct tip edge, it does not produce a distinctive overall handaxe morphology. This corroborates a morphometric study of the Boxgrove handaxes, which found that most tranchet flaking had no effect on shape (García-Medrano et al., 2018).

To further explore the distinction between Hitchin and Swanscombe, we looked at the mean models of handaxes from the two sites. These indicate that they are distinguished by the Swanscombe handaxes being pointier and to some extent by the unusual profiles of the plano-convex and twisted handaxes from Hitchin (Figure 4).

Comparing Hitchin and Swanscombe with the MIS9 assemblage from Broom shows significant differences between both MIS11c assemblages and Broom (Table 7), with the cluster analysis further showing the MIS11c assemblages are more similar to each other than either is to Broom (Figure 5). Figure 5 shows that Broom occupies a wide range of variability in its first two components, occupying its own area on the right of the distribution, and overlapping with much of the Hitchin and Swanscombe distributions, including in areas they do not overlap with each other.

Next we analysed the shape occupied by biface types rather than assemblages (Figure 6). As there were only two asymmetrical pieces they are not discussed in the following analysis. For the first two principal components there are significant areas of unique shape space occupied by each type except plano-convex and twisted pieces (Figure 6). This is likely because the first two components are concerned with gross morphology and are not discriminating the details of the position of the edge in relation to the profile of the piece which defines plano-convex and twisted handaxes. Wilcoxon rank-sum tests on interpoint distances, (taking into account the entirety of shape space), indicate significant differences between cordate handaxes and the types they overlap with, between triangular handaxes and all the types that they overlap with, and between limandes and cleavers which overlap with each other (Table 7). Plano-convex and twisted handaxes are significantly different from triangular and cordate handaxes respectively, showing that the former types are distinguishable by lower order parameters of shape variation than the first two principal components. Wilcoxon rank-sum tests on interpoint distances showed that neither rock type (flint vs. chert, N=150, rank-sum=21844, p=0.33), nor blank type (cobble vs. flake, N=40, rank-sum=1500, p=0.25) were significant factors in explaining shape variation.

One explanation for the distribution of shape variation is that the designated types are simply capturing extremes of continuous variation within sites. However, the wide variety of forms at Broom, including both ficrons and ovates from opposite ends of the main spectrum of shape variation, and the presence of asymmetrical pieces not represented in the other assemblages, are difficult to accommodate in variation around a single modal type. The lack of twisted and plano-convex pieces in assemblages with similar ranges of planforms such as Swanscombe Middle Gravels (White et al., 2019), indicates the distinctiveness of these types at Hitchin. The double distinctiveness of planform and edge position in the case of plano-convex and twisted handaxes (overlapping in planform with triangular and cordate handaxes respectively) (Figure 7), shows that these are genuinely different types.

Table 7. Results of Wilcoxon rank-sum tests comparing interpoint distances between biface types for PCA 5.

Comparison	N	rank-sum	p
Cordate v. Ovate	74	4308	<0.01
Cordate v. Twisted	52	1682	<0.01
Cordate v. Triangular	70	3220	<0.01
Triangular v. Limande	34	662	<0.01
Triangular v. Plano-convex	35	846	<0.01
Triangular v. Ficron	36	946	<0.01
Limande v. Cleaver	21	368	<0.01

Conclusion

The meaning of handaxe form has been the subject of debate since the early discoveries of these objects. In our sample of British Acheulean handaxes, incidental variables have a varying influence on handaxe morphology. Reduction intensity did not have a significant effect once other variables were taken into account. Initial clast size had a significant but very weak effect. There was an allometric effect of handaxe length with longer handaxes tending to be narrower (and pointier), likely due to the ergonomic constraints of these handheld objects (Gowlett and Crompton, 1994). The most important determinant of handaxe shape was however the site to which the specimen belongs.

We tested the hypothesis that site-wise differences in handaxe shape reflected different waves of colonization with divergent traditions of handaxe making in different temperate periods (Bridgland and White, 2014; White et al., 2018). Our results show strong support for this hypothesis, with the MIS13 assemblages of High Lodge and Boxgrove not significantly different to each other, while both are significantly different to the MIS11c assemblages Hitchin and Swanscombe. This is despite High Lodge and Hitchin both being in eastern England (Figure 1), and despite Boxgrove and Hitchin handaxes both being made on primary clasts of flint. Within MIS11c there is a significant difference between Hitchin and the Thames valley assemblage from Swanscombe, supporting the hypothesis of White and colleagues (2019) that there were different geographical traditions in Britain at this time. Part of the distinctiveness of Hitchin may derive from its representing two occupations. The cluster analysis showed that despite the significant difference, Hitchin and Swanscombe are still more similar to each other than either is to the MIS13 assemblages. Likewise, Swanscombe and Hitchin are more similar to each other than either is to the MIS9 assemblage of Broom. This is despite both Broom and Hitchin bifaces being made on primary clasts, while those from Swanscombe were made on secondary clasts.

Acheulean populations recolonizing Britain must have had their origins in the more continuously occupied regions to the south. The Somme Valley in northern France provides the nearest well-studied Acheulean sequence (Commont, 1912). Here, the MIS15/14 transition site of Carriere Carpentier has yielded cordate handaxes flaked around the entire perimeter and with tranchet removals, similar to those from Boxgrove in MIS13 (Antoine et al., 2016). At the MIS12 site of Cagny-la-Garenne pointed forms and handaxes with clumsy twisted edges are evident, presaging those that occur in the MIS11 sites in Britain; while at MIS10-9 sites in the Somme valley there is a wide variety of handaxe forms and shaping methods (Lamotte and Tuffreau, 2016) consistent with the diversity seen in the MIS9 occupation of Broom. That equivalent handaxe assemblages to the British Acheulean occur in the preceding marine isotope stages in France, suggests that the traditions represented by these distinctive handaxes types were maintained over tens of thousands of years, consistent with the longevity in particular Acheulean traditions documented elsewhere in the world (Sharon et al., 2011).

The second part of our analysis attempted to morphometrically evaluate the named handaxe types in the British Acheulean. The analysis showed that most types occupy significant areas of unique shape space for the first two principal components and that all types are statistically distinguishable. For plano-convex and twisted pieces, the double distinctiveness of plan shape and edge position indicates these are genuinely different types. Rock type and blank type do not appear to be driving this variation. Elsewhere we have argued for the importance of imitation and over-imitation in maintaining the Acheulean (Nielsen, 2012; Shipton, 2010, 2019a; Shipton and Nielsen, 2015), but such high-fidelity social reproduction of knapping sequences is not enough in itself to explain the distinctive similarities observed here. The relatively small, irregular-shaped, and internally variable flint and chert nodules used to make these British handaxes require dynamic adaptation of reduction sequences to produce the same final forms. Importantly, conceptually different reduction sequences were sometimes used to produce the same types. For example, plano-convex handaxes from Hitchin, triangular handaxes from Swanscombe, and ovate handaxes from Broom were all made on both flake and cobble blanks.

Multiple distinct types are apparent in both these assemblages and others in Table 1. While in the case of Hitchin this may reflect a palimpsest, such an explanation cannot hold for all sites. This intra-assemblage variability suggests that handaxe forms were not merely conforming to the most common model with random drift of that model between assemblages. Further analysis, with larger sample sizes, is needed to test whether, for example, MIS13 ovates and cordates occur on a continuum, or if there is a bimodal distribution of different types. The variety of shapes seen in the Broom handaxes, including those not present at the other sites, and which are thought to derive from a single occupation (Hosfield and Chambers, 2009), indicates multiple distinct types.

For a knapper skilled enough to produce some of the refined pieces studied here (Figure 2), the morphology of the plan, profile, and edge, would have been salient features of the handaxe (Hiscock, 2014). Between 18 and 24 months old, human children begin to recognize three dimensional shape categories, an ability that appears to emerge from the learning of object names (Pereira and Smith, 2009; Smith, 2009; Yee et al., 2012). We suggest that to be able to make the distinctive forms observed in the British Acheulean, their makers would have needed to recognize them as particular types.

Different forms may have appeared as emergent properties of the idiosyncrasies of expert knappers, whose handaxes were preferentially replicated. However, in transmission chain experiments where handaxe-like forms are recreated in mediums that do not require specialized skill, deviation from the initial shape is rapid (Schillinger et al., 2016; Shipton et al., 2018). To maintain the kinds of specific handaxe types seen in Britain from MIS13 onwards may have required expected norms of handaxe shapes. Many of the British Late Acheulean handaxes types are difficult to create. Plano-convex and twisted pieces for example, are very rare in the wider Acheulean world (Gallotti et al., 2010), while the distinctive tranchet resharpening technique in use at Boxgrove and High Lodge, is a highly risky knapping strategy that is liable to break or blunt a biface if done incorrectly (García-Medrano et al., 2018). To reproduce such forms may have required the additional motivation of socially resonant behavioural norms.

The developmental basis of normativity is to be found in over-imitation, the uniquely human tendency to replicate all intentional actions of a demonstrator, including those that are causally redundant (Nielsen et al., 2014). Over-imitation, we suggest, is evident in the arbitrary conformity seen in complex Acheulean manufacturing sequences from ~1 million years ago (Shipton, 2019a; Shipton and Nielsen, 2015; Shipton et al., submitted). It may be that from this time we begin to see arbitrary normative conformity in handaxe types at sites like Isenya in eastern Africa, which has some distinctive elongate and skilfully made forms (Shipton, 2018).

Normativity is an intuitively underappreciated human trait (Cialdini, 2007), yet it underpins diverse aspects of our behaviour including language, co-operation, and morality (Roughley and Bayertz, 2019). Normativity would have conferred key advantages to Acheulean hominins in a niche of co-operative hunting of mega-herbivores in large groups (Domínguez-Rodrigo and Pickering, 2017). Normativity is critical to expectations of particular roles in co-operative tasks (Tomasello and Hamann, 2012), something that would have had selective salience when hunting large and dangerous mammals like elephants (Ben-Dor et al., 2011; Solodenko et al., 2015). To maximise the fitness benefits of large nutritious carcasses and spread the risks of unpredictable procurement, normative rules for sharing throughout a large group would have been advantageous. Such rules would have engendered the transport of carcass elements to group aggregation sites, where the individuals who had incurred the risk of the hunt shared their gains with others (Agam and Barkai, 2016; Moreno et al., 2015), and where freeloading would have been policed and discouraged by similar collectively understood behavioural codes (Boyd et al., 2003). By the late Middle Pleistocene, normativity had perhaps evolved beyond mere conventions to something that carried external social pressure (Anderson and Dunning, 2014). The existence of such social norms would explain why hominins in the British late Acheulean persisted in making handaxes types that were difficult and risky to produce when more generic forms would have sufficed.

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Figures

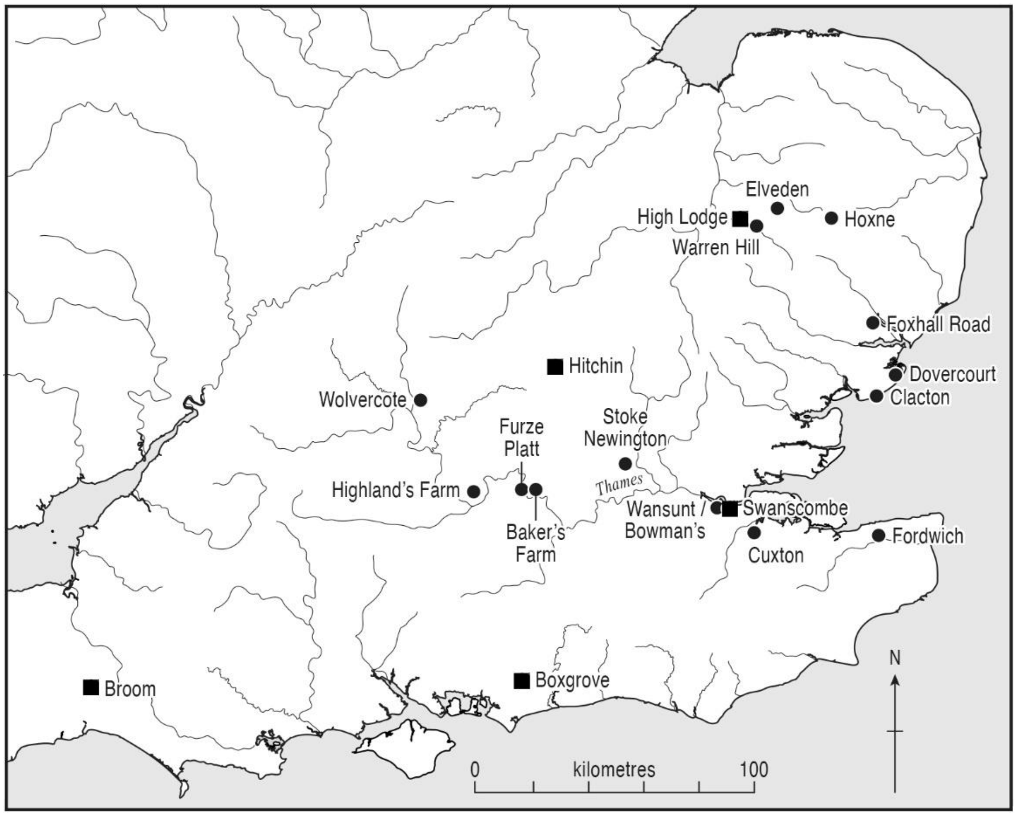

Figure 1. The location of the British Acheulean sites shown in Table 1. The sites shown by squares were sampled for this study.

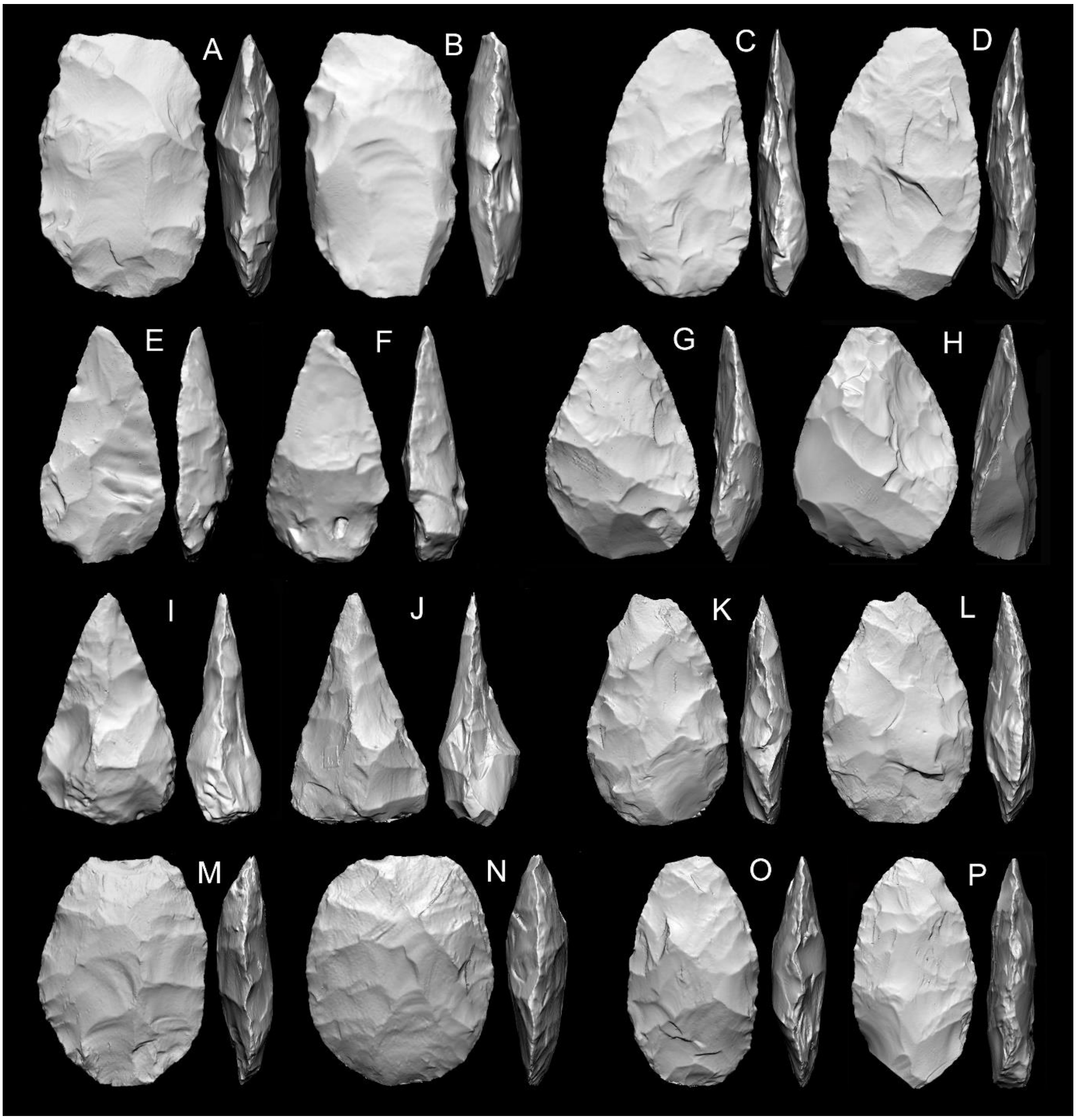

Figure 2. Plan and profile views of some of the British bifaces used in this study, showing matched pairs of biface types from each site. A and B are cleavers from Broom; C and D are asymmetrical giants from Broom; E and F are plano-convex handaxes from Hitchin; G and H are twisted handaxes from Hitchin; I and J are triangular handaxes from Swanscombe; K and L are tranchet cordates from Boxgrove; M and N are tranchet ovates from Boxgrove; O and P are limandes from High Lodge. Note that the handaxes are shown at a standardized size to facilitate comparisons of shape.

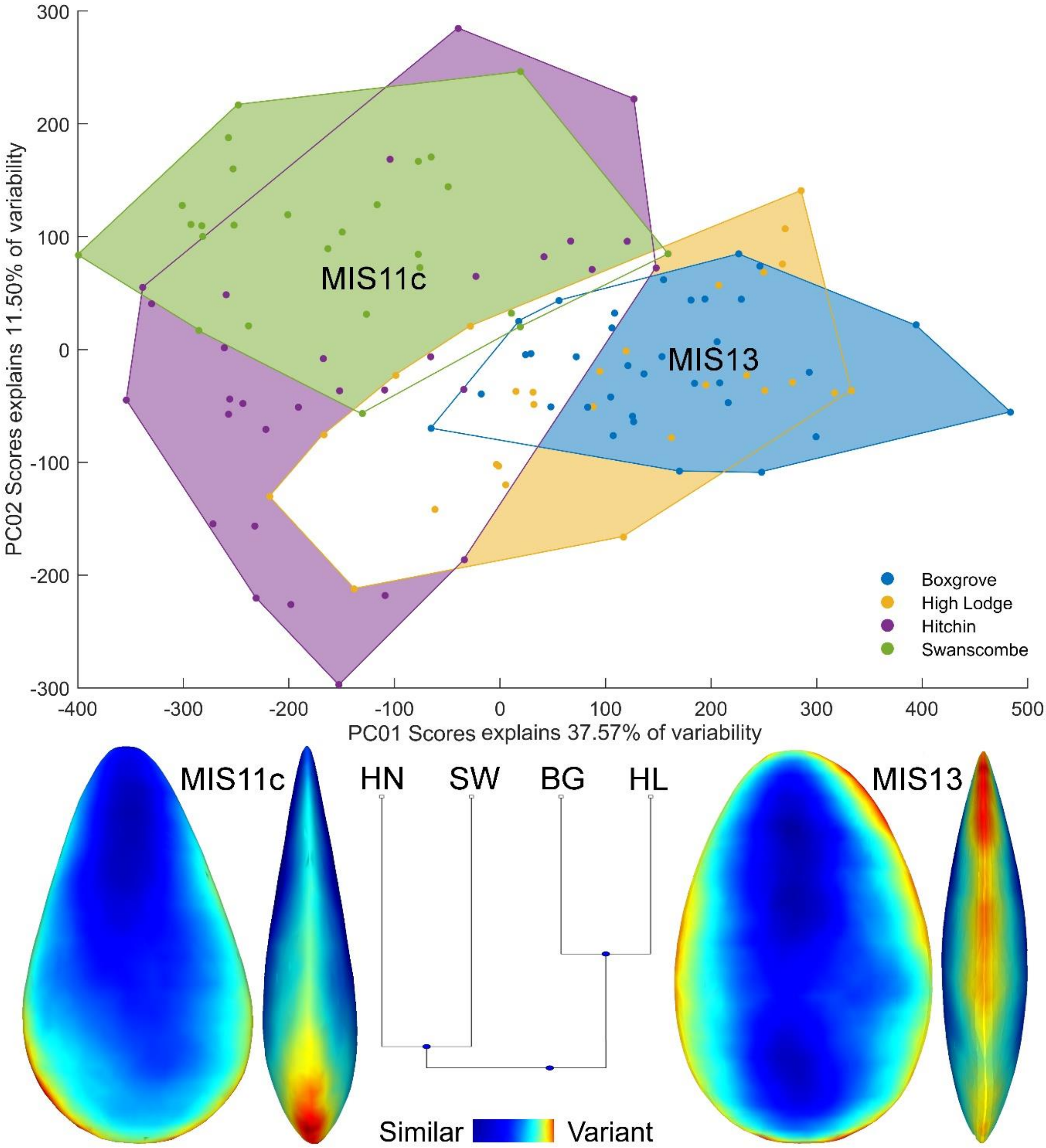

Figure 3. Scatter plot showing the distribution of handaxes from Boxgrove (BG), High Lodge (HL), Hitchin (HN), and Swanscombe Middle Gravels (SW) according to the first two principal components. Groups are outlined with convex hulls. Note the Boxgrove convex hull is shown on top of High Lodge, and the Swanscombe convex hull is shown on top of Hitchin. The area of overlap between the two marine isotope stages is left unshaded. Models below show the average form of MIS11c and MIS13 handaxes, with heat maps showing within group variation. Note the contrast in the points of maximum breadth and thickness. The variable right tip on the MIS13 handaxes reflects the presence or absence of tranchet flaking. The dendrogram in the lower middle shows the hierarchical clustering of group mean shapes. Note that Boxgrove and High Lodge are more similar to each other than either is to Hitchin or Swanscombe.

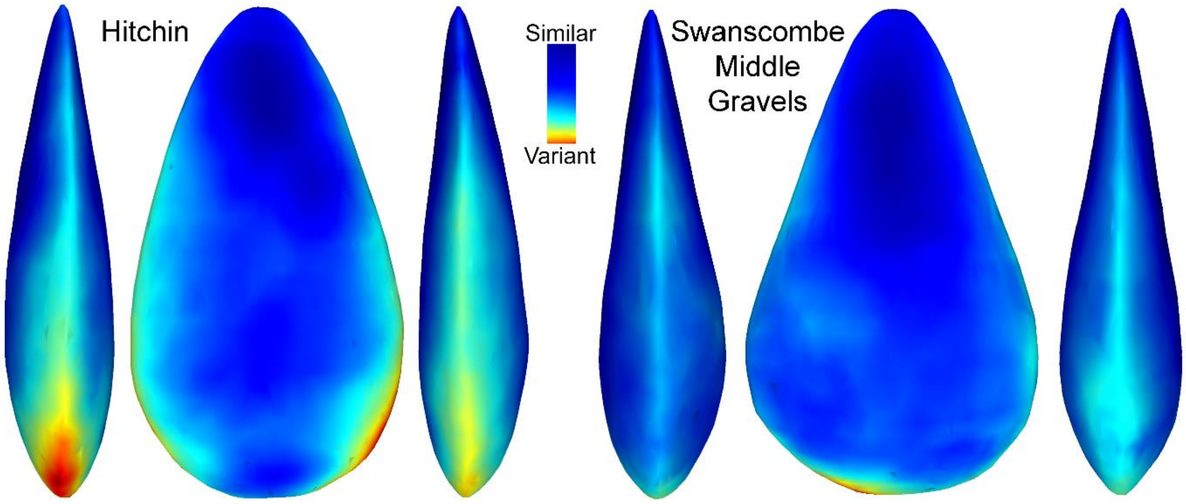

Figure 4. Mean forms for Hitchin and Swanscombe. Heat maps show most variable regions within assemblages. Note the convex edge of the Hitchin model in plan compared to the straight edges of the Swanscombe model. Edge morphology is more variable in the Hitchin model.

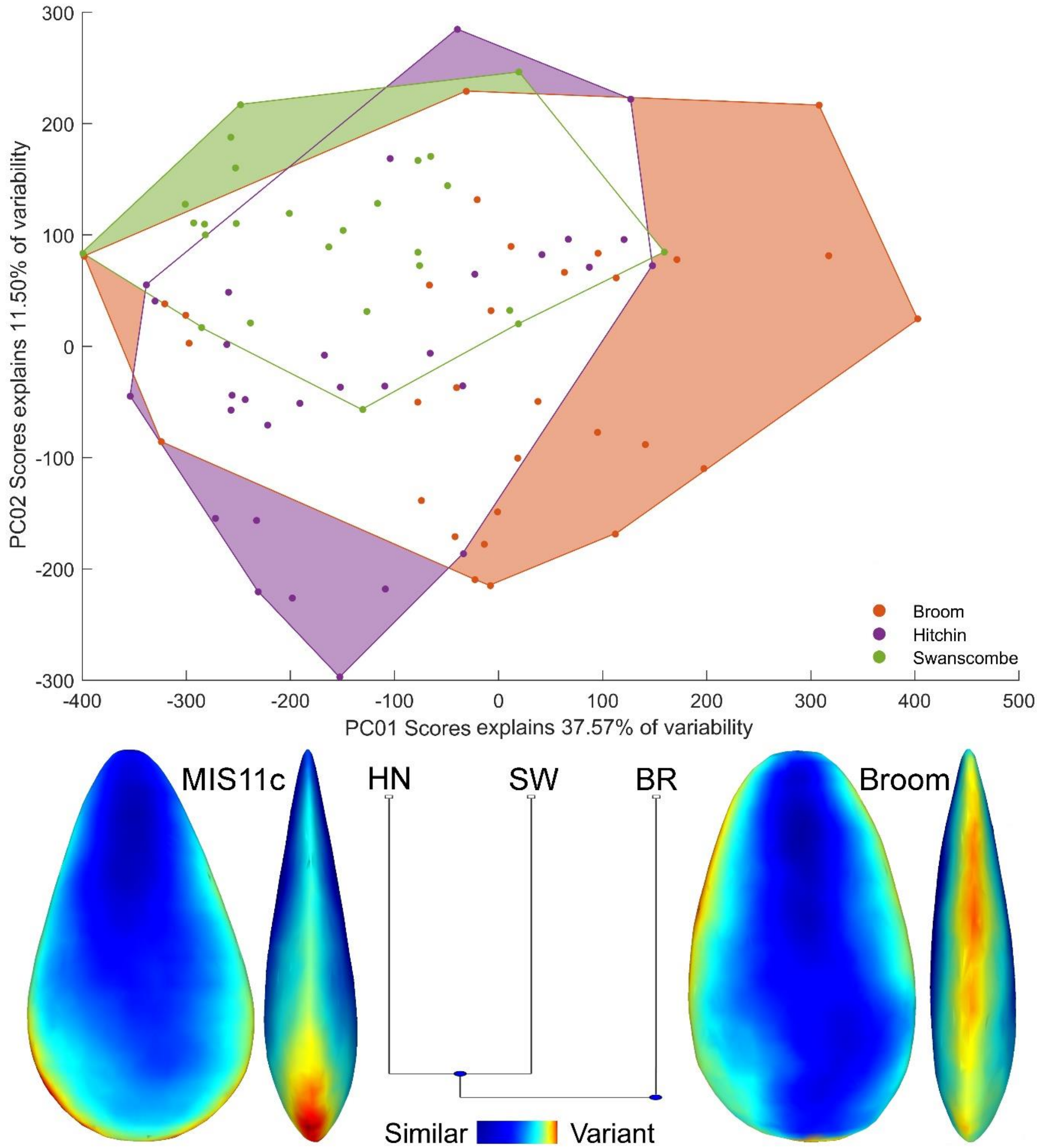

Figure 5. Scatter plot of the first two principal components of biface morphology for MIS11c assemblages Hitchin (HN) and Swanscombe (SW), and Broom (BR). Convex hulls are drawn around the three distributions with Swanscombe overlain on Hitchin and areas overlap between the MIS11c assemblages and Broom left unshaded. The dendrogram in the lower middle shows the hierarchical clustering of group mean shapes. The model on the lower left show the mean form for MIS11c bifaces and that on the right for Broom. Heat maps show the areas of highest within group variation. Note the point of maximum thickness is proximally located on the Broom model, similar to the MIS11c model, but the tip is rounded unlike the pointed MIS11c model.

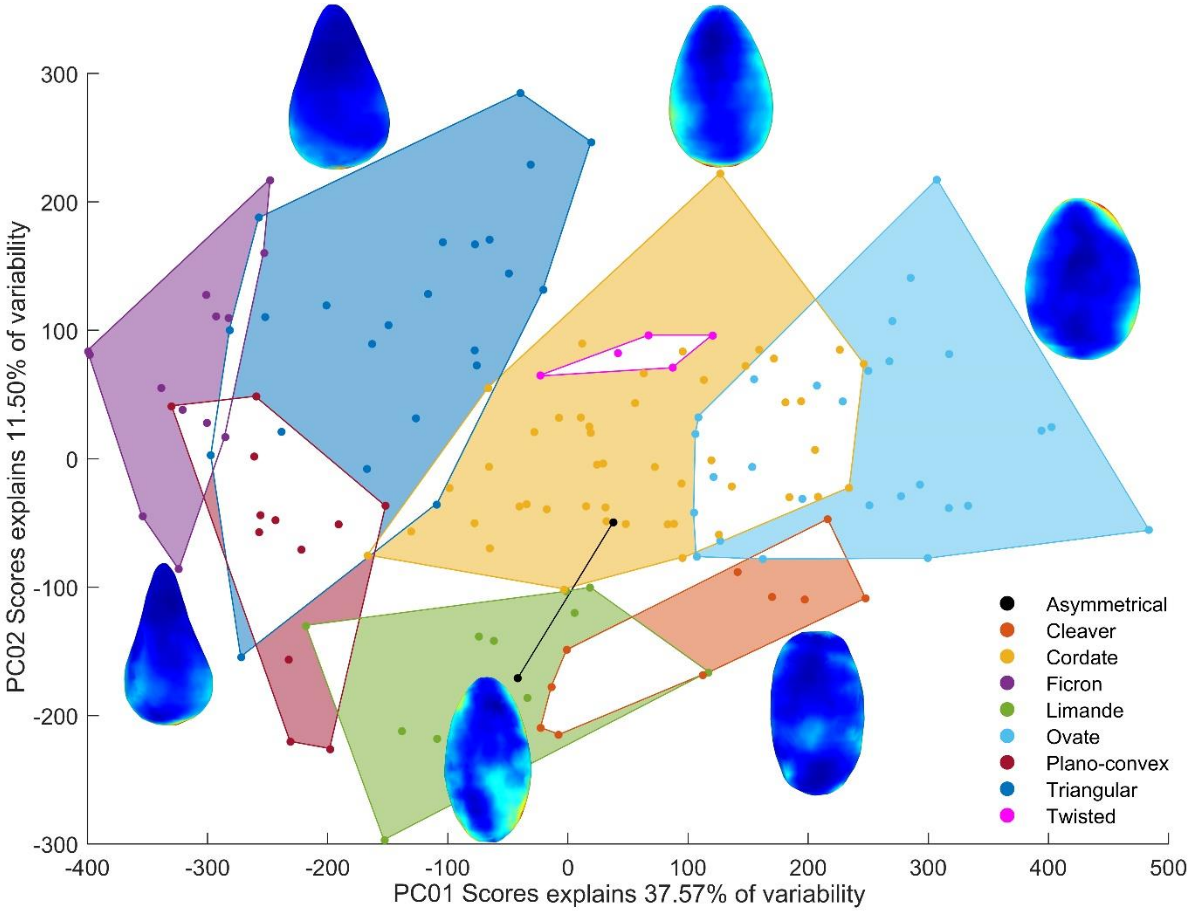

Figure 6. Scatter plot of the first two principal components of all bifaces used in this study, grouped by biface type. Convex hulls denote the area of shape space occupied by each type with overlapping areas unshaded. Note that there are large areas of unique shape space for each of the types, except plano-convex and twisted pieces. Planforms of mean type shapes are shown next to each convex hull except plano-convex, twisted, and asymmetrical pieces. Three of the Boxgrove ovates on the bottom left of the distribution are U-shaped with transverse bits formed by a tranchet blow and in some typologies might be considered cleavers.

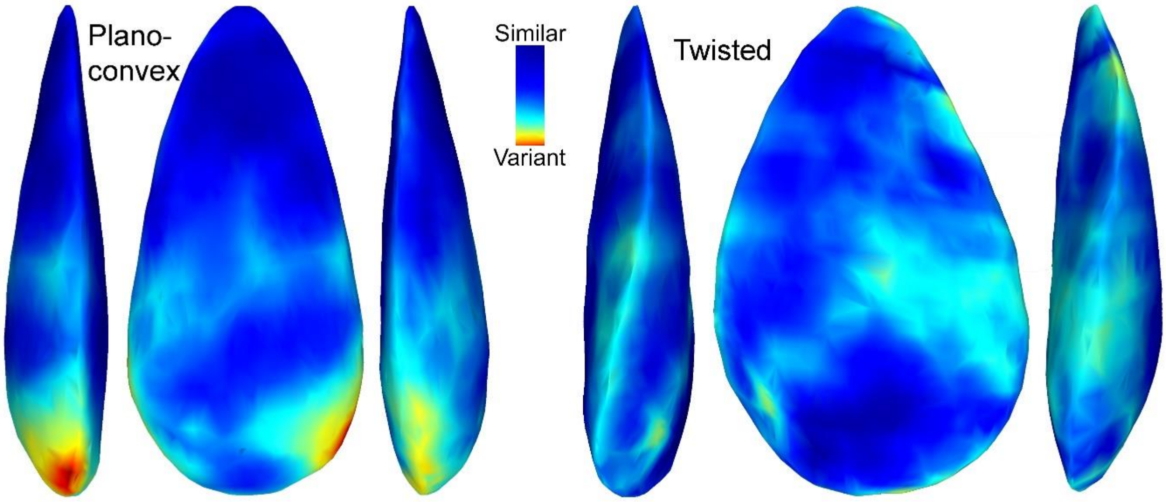

Figure 7. Mean forms for plano-convex and twisted handaxes (all from Hitchin). Note as well as the distinctive edges after which these two types are named, they also have contrasting planforms with plano-convex pieces being more elongate.